Water Power Development At Iowa Falls, Iowa

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1907

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WATER POWER DEVELOPMENT

At

IOWA FALLS, IOWA

A THESIS

Presented By

Charles O. Dowdell

To The

President And Faculty

Of

ARMOUR INSTITUTE OF TECHNOLOGY

For The Degree Of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Having Completed The Prescribed Course Of Study In

CIVIL ENGINEERING

June 1, 1907

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Water Power Development At Iowa Falls, Ia.

Iowa Falls is a town of 3500 in Hardin County Iowa on the bluffs of the Iowa River. The town gets its name from a succession of rapids and small falls in the river, which at this point cuts its way through inter-stratified sandstone and limestone inclined in an opposite direction to the flow of the stream. As a result of this cutting, the river flows swiftly and with a fall of fifty feet between curiously carved rock bluffs thirty to eighty feet high for a distance of four miles. The beauty of the scenery, good boating and fishing, brings annually a large number of visitors to the Chautauqua Assemblies and other gatherings in the parks on either side of the river.

A demand for a large amount of power in excess of that ordinarily furnished to a town of the same size, has been made for the operation of lights through the Chautauqua grounds and in the various pleasure parks, which line the river banks on either side. This demand has been partly met with by the local electric light plant, which having a monopoly of the field, charged a high rate for the service; and, the plant being over-loaded, breakdowns are frequent, and the service of the poorest quality. The construction of a local and inter-urban trolley line is planned, which gives a market for a large amount of power. Another market is the new shops, which the Illinois Central Railroad

19518

plans building at this point.

The object of this Thesis is the profitable development of the available water power at Iowa Falls. A small fraction of the power is developed by a fourteen foot log dam built in 1857. This old dam gives a ten foot head under favorable conditions of moderately low water, and furnishes power to run a flour mill. It leaks a large amount of water and requires costly repairs annually. The owners have decided to abandon the mill, and enter upon the construction of a much larger dam farther down stream, where additional fall can be obtained, and with the water power obtained, operate a hydro-electric plant. It is with the design and construction of this project, that we wish to confine ourselves.

The site of the proposed improvement is at a point just above the Illinois Central Railroad Company's bridge, one-half mile below the old dam, and one-fourth mile above the foot of the rapids. After running a set of levels from the lower to the upper end of the rapids, and making a stadia survey of the vicinity of the lower end, soundings were taken down to the rock surface, by means of a steel rod forced down by hand or driven by a maul, along the length of the dam and power-house site. From this data a map and profile of the site were drawn.

This site was chosen for several reasons: A point farther down stream would cause the river to back up Rock Run

Canon, and flood a portion of the town. The gorge of the river is narrowest at this point lessening the length of embankment to be built. The rapids below the dam fall ten feet in one-fourth mile; and this slope will cause the water in the tail-race to flow away very rapidly. The railroad being close at hand, material can be unloaded within reach of the cableways and derricks on the work.

A solid masonry dam with the power-house at the south end of it was at first contemplated. The stone was to be hauled to the work from the quarry of the Ellsworth Stone Co. three-fourths of a mile down the river over a small track to be built along the north side of the stream. The plan was changed after a study of the foundation by the adoption of a reinforced concrete dam, consisting of a reinforced slab supported by concrete buttresses, in place of a solid dam. A good quality of crushed limestone can be obtained at the Ellsworth quarry, and also at the Barber Asphalt Paving Co's. quarry across the river from it.

The foundation is of very hard sandstone of a kind used as building stone and dips at a six per-cent slope in an opposite direction to the river flow. This is bared at the center of the stream, but covered with earth and rotten rock near the edges. The profile shows the rock surface very nearly level. At the north end of the dam is an overhanging cliff; and at the other end the rock surface is inclined upward with about half the inclination of the sur-

face slope. At this end is to be the power house; and the rock is to be excavated to the general level of the river for the tail races.

The type of dam is similar to that patented and built by Messrs. Ambursen & Sayles Co.; and consists of a sloping upstream face or deck with a slope of one to one supported on concrete buttresses, eleven feet center to center. The deck is a continuous reinforced concrete slab designed to support the weight of the water. The resultant of the water pressure cuts the base at a point eight feet from the crest on the upstream side, or at a point four feet from the center of the length of a buttress, and on the upstream side of the center, making the dam safe against overturning and sliding.

As the rock excavation for a separate spillway would require too large an outlay of capital, the dam is designed as an overflow dam. The dam is thirty-five feet high; and a direct fall of that distance would soon scour even the hardest sandstone and undermine the toe of the structure; so, a curved down stream face with a wide apron delivering the water parallel to the river bed was adopted.

This form of over flow will allow the large masses of ice, which are dangerous to direct fall types of overflow dams, to safely pass the structure. A vacuum is formed between the dam and the stream passing down the curved face, which causes a trembling of the structure. This

trembling is stopped by admitting air, and destroying the vacuum, through pipes from the inside of the dam.

It is planned to use flashboards during periods of low stages of the river to obtain an additional head on the turbines and additional power. They are held in place by steel rods bent over at the top and fitted in pipe sleeves in the concrete. An elevated walk on the inside of the dam gives access to the lower end of these rods; and,, when the flashboards are to be released in flood periods, by twisting the rods one-half turn they can be drawn down releasing the boards which float away.

The power house forms the south one-third of the dam; and contains three units, each a six hundred K.W. direct current generator driven by two "Samson" turbines mounted on the same horizontal shaft. Between the power house and shore, and also between the north end of the dam and the shore, are earth embankments containing concrete core-walls. These embankments are to be constructed with a slope of one and one-half horizontal to one vertical.

A concrete cut-off wall five feet thick and extending six feet below the rock surface is placed at the heel of of the dam, and extends the full length of the structure. Seepage water is drained from under the dam through the drains under the apron. Arched openings through the buttresses near the rock surface permits the free circulation

of water about under the dam.

Estimates of the maximum flood and the minimum dry weather flow are obtained from miscellanious guagings kept at the old mill. The head on a weir one hundred and fifty feet long was measured by means of a scale immersed with its zero on the same level as the crest of the weir. This guage has been in place for eleven years; and on checking it with level and rod, it was found to read about one-half inch too high. The data obtained was:

Maximum Head.	Minimum Head.
6 feet.	1 foot.

The discharge, as calculated from the formula,

$$Q = \frac{2}{3} C B \sqrt{2g}\, H^{\frac{3}{2}} \qquad (C = .7)$$

Maximum Discharge.	Minimum Discharge.
8242.0 Cu. Ft. Sec.	561.4 Cu. Ft. Sec.

The minimum flow lasted for a period of nine days. The minimum flow estimated for the development of power is six hundred cubic feet per second, as there is sufficient storage in the reservoir to provide the additional amount without lowering the head more than three and one-half feet.

The dam is designed to sustain a head of five feet upon the crest; this being the head required to produce the above maximum discharge over it. The pressure against the deck acts normal to it; and for one square foot of area at a depth h the pressure would be,

$$P = 62.5h.$$

The pressures in pounds per square foot corresponding to various values of h are as follows:

h In Feet.	P In Lbs.	h In Feet.	P In Lbs.
5.0	312.5	25.0	1562.5
10.0	625.0	30.0	1875.0
15.0	937.5	35.0	2187.5
20.0	1250.0	40.0	2500.0

These values of P are the live load upon the slab forming the deck. The dead load producing bending is equal to the weight of the slab multiplied by the sine of 45.

It was decided to design the slab as being continuous over the supports, so that it would not crack at these points. The theoretic value for the bending moment over the support of a beam fixed at the supports is

$$-M = \frac{wl^2}{12} = \frac{Wl}{12}$$

and at the center of the span

$$M = \frac{wl^2}{24} = \frac{Wl}{24}$$

where

l the length of the span in inches.

w the load in lbs. per inch of length.

W wl the load over the whole span

As is seen, the negative moment over the support is twice the positive moment, and therefor determines the depth of the slab, as will be shown later.

After trying various values varying from 8 to 15 feet for the distance from center to center of buttresses, the

value 11 feet was chosen as the most economical of forms and material. Using this spacing the thickness of each of the buttresses becomes 2 feet 6 inches for a bearing value of 10 tons per square foot. This thickness tapers off to 2 feet at the top.

If the slab were to be designed as a simple beam the bending moment would be

$$M=\frac{wl^2}{8}=\frac{Wl}{8}$$

where the notation is as above with the exception of l, which in this case is 2 feet to 2 feet 6 inches less than the l for the continuous beam.

$$M=\frac{w(l)^2}{12}>M=\frac{w(l-2)^2}{8}>M=\frac{w(l-2.5)^2}{8}$$

The value of the negative moment is greater than the positive moment in a simple beam of a length equal to the distance from buttress to buttress; and therefor determines the the depth of the slab.

The resisting moment of the beam is expressed by the equation below obtained from "Concrete Plain And Reinforced" by Taylor and Thompson.

$$M_R=Sbd^2\left[\frac{2S}{C}\left(1-\frac{S}{Cr}\right)\right]\left[1-\frac{1}{3\left(1-\frac{S}{Cr}\right)}\right]$$

Or

$$M_R=Kbd^2$$

In which

h = height of beam.

b = breadth of beam.

p = ratio of cross-section of steel to cross-section of beam above center of gravity of steel.

C = unit pressure in outside fiber of concrete.

S = unit tension in steel.

$r = \frac{E_s}{E_c}$ = ratio of moduli of elasticity of steel to concrete.

M_R = moment of resistance.

K = constant for a given steel and a given concrete.

For a value of 15 for r, 16000 for S and 500 for C, K has a value of 71. These values were the ones used in calculating the thickness of the slab forming the deck, and also the foot walk under the dam.

The concrete is to be a 1:2:4 mixture in the deck, overfall and core-walls of embankments, and a 1:3:6 mixture in the buttresses, retaining walls and power house. Crusher run limestone not larger than one and one-half inch size for the 1:2:4 mixture, and not larger than four inches for the 1:3:6 mixture is to be used with sand obtained at a bank one mile from the site. Concrete rubble can be used in the retaining walls laid in the coarser mixture; and it is planned to use for this the rock from the excavations on the site.

Temperature stresses in the water tight deck and overfall are to be provided for by making the top and bottom reinforcement continuous, the steel not stressed by bending taking the temperature stress, there being a sufficient percentage of it to do so safely. Rods are placed about all openings to prevent cracking from shrinkage or movements due

to temperature stresses.

The selection of turbines to drive the generators was made after a consideration of the various requirements of an engine driving a generator: The engine must give a constant speed under all loads, in order to maintain the voltage. It must have sufficient power to provide for an overload upon the generators. A quick acting governor is necessary for sudden fluctuations of load. The efficiency should be the greatest at or near the normal load placed upon it.

A discharge of 600 cubic feet per second falling 30 feet gives a theoretical Horse Power of,

$$\frac{600\ 62.5\ 30}{550} = 2045.5 \text{ Horse Power.}$$

In electrical units this is,

$$.746\ 2045.5 = 1525.9 \text{ Kilowatts.}$$

A "Samson" turbine gives 83.5% efficiency at 3/4 gate opening; and taking the efficiency of generators and penstocks as each 98.0%, the developed power is,

$$1525.9\ .835\ .98\ .98 = 1223.5 \text{ Kilowatts.}$$

Two 600 K.W. generators are sufficient; but a third one is to be installed to provide for breakdowns and excessive over loading upon the others. Each generator is capable of operating at a 25% over-load continuously and at a 50% overload for four hours without over-heating.

Two 40 inch turbines drive each generator. At full gate opening each developes 531 Horse Power using 11565 cu-

bic feet per minute; and at 3/4 gate opening each developes 400 Horse Power using 8675 cubic feet per minute. The speed ranges from 223 R.P.M. at full gate opening to 205 R.P.M. at 3/4 gate opening. The turbines are of the mixed flow type, and are mounted on a horizontal shaft 15 feet above the tail-water level, and discharge through a central draft tube, which terminates just below the level of the surface of the tail-water. The end thrusts on the shaft are opposed, and each neutralizes the other. A steel cylinder flume encases the turbines, and is placed at the end of the penstock.

The power is to be delivered at 250 and 500 volts for light and power respectively. As there are to be no long transmission lines, high voltages and an elaborate switch board are unneccessary.

Bibliography

Books

Taylor and Thompson,
"Concrete Plain And Reinforced."

Reid,
"Concrete And Reinforced Concrete Construction."

Buel and Hill,
"Reinforced Concrete."

Frizell,
"Water Power."

Bodmer,
"Hydraulic Motors, Turbines And Pressure Engines."

Church,
"Hydraulic Motors."

Wood,
"Theory Of Turbines."

Merriman,
"Treatise On Hydraulics."

United States Geological Survey,
"Water Supply Paper #180."

Greene,
"Structural Mechanics."

Carpenter,
"Experimental Engineering."

Franklin and Esty,
"Elements Of Electrical Engineering."

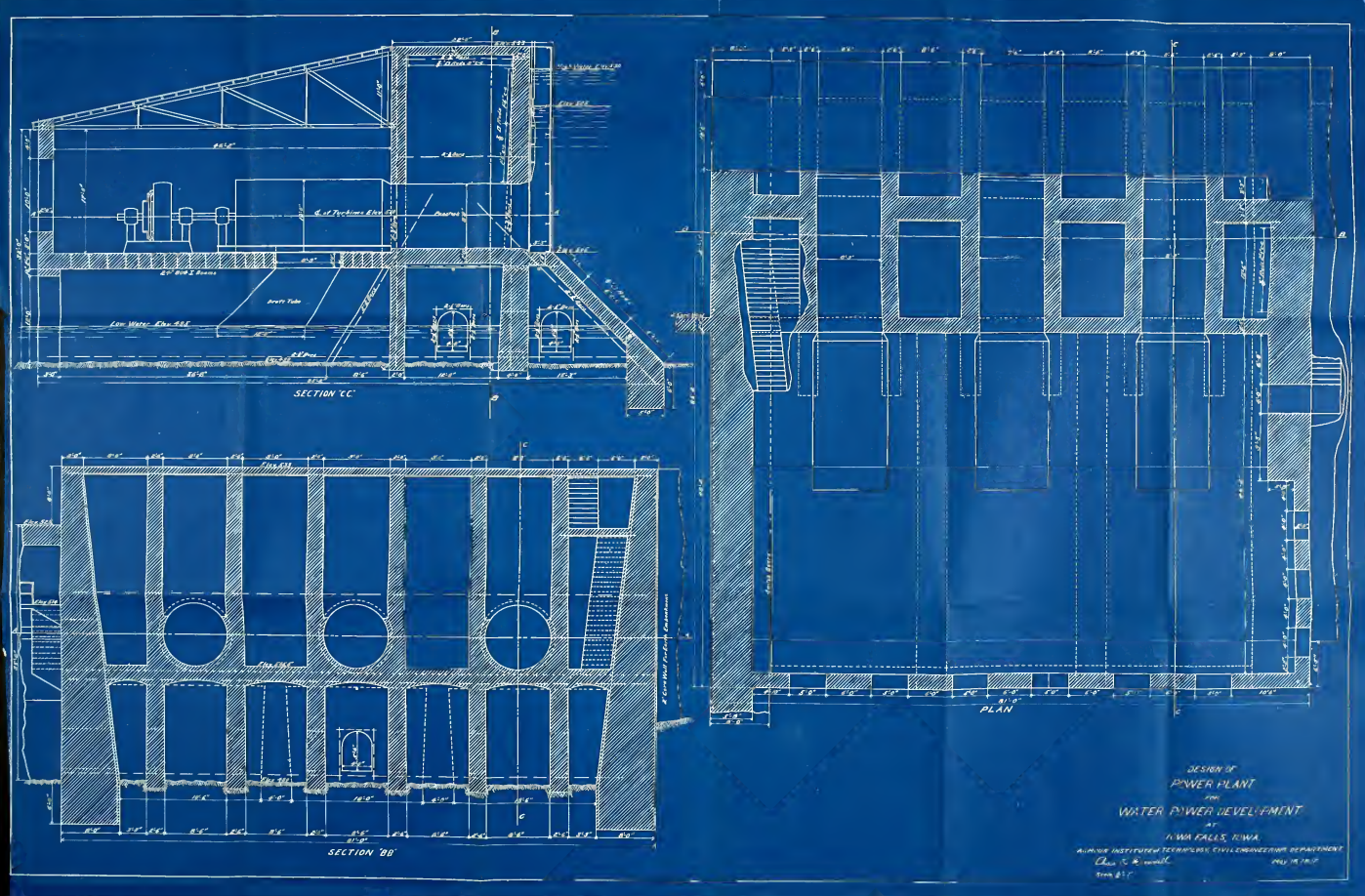
Periodicals

Engineering News, 50:403, 568,
"Hollow Concrete-steel Dam at Theresa, N.Y."

Engineering News, 50:500,
"Editorial."

Engineering News, 53:448,
"Hollow Reinforced Concrete Dam."

Engineering Record, 51:266,
"Construction of the Schuylerville,(N.Y.) Concrete Dam."


SECTION "C.C."
Draft Tube
Low Water Elev. 855
SECTION "BB"
PLAN
DESIGN OF
POWER PLANT
FOR
WATER POWER DEVELOPMENT
AT
NIAGARA FALLS, NIAGARA.
ALBANY INSTITUTE OF TECHNOLOGY, CIVIL ENGINEERING DEPARTMENT.

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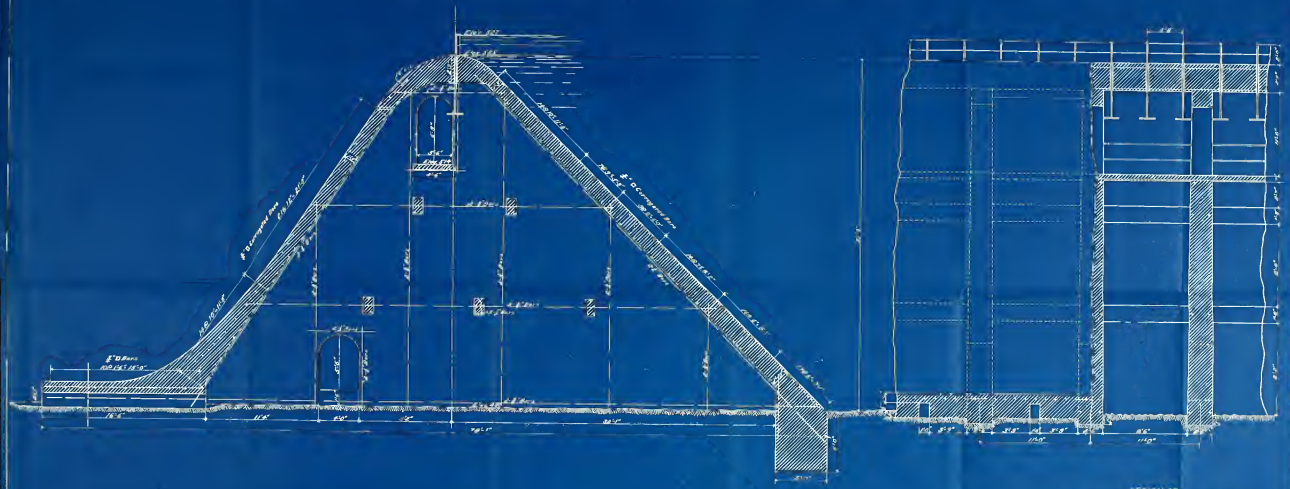
1" = 50'



DESIGN OF
REINFORCED CONCRETE DAM
FOR
WATER POWER DEVELOPMENT
AT
IOWA FALLS, IOWA.

ARMOUR INSTITUTE OF TECHNOLOGY CIVIL ENGINEERING DEPARTMENT

Chas. R. Gwinn

MAY 28, 1907

SCALE 1"=

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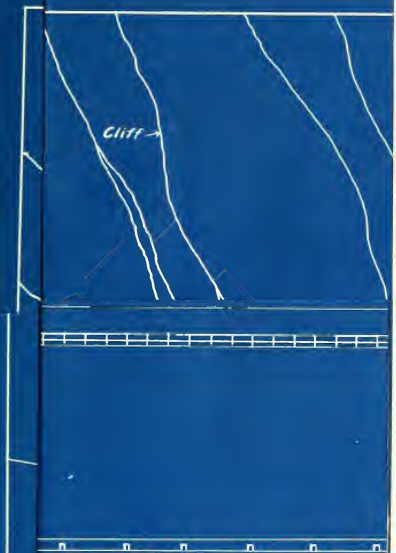


MAP OF LOCA

AND

GENERAL ELEVATION

FOR

WATER POWER DE

AT

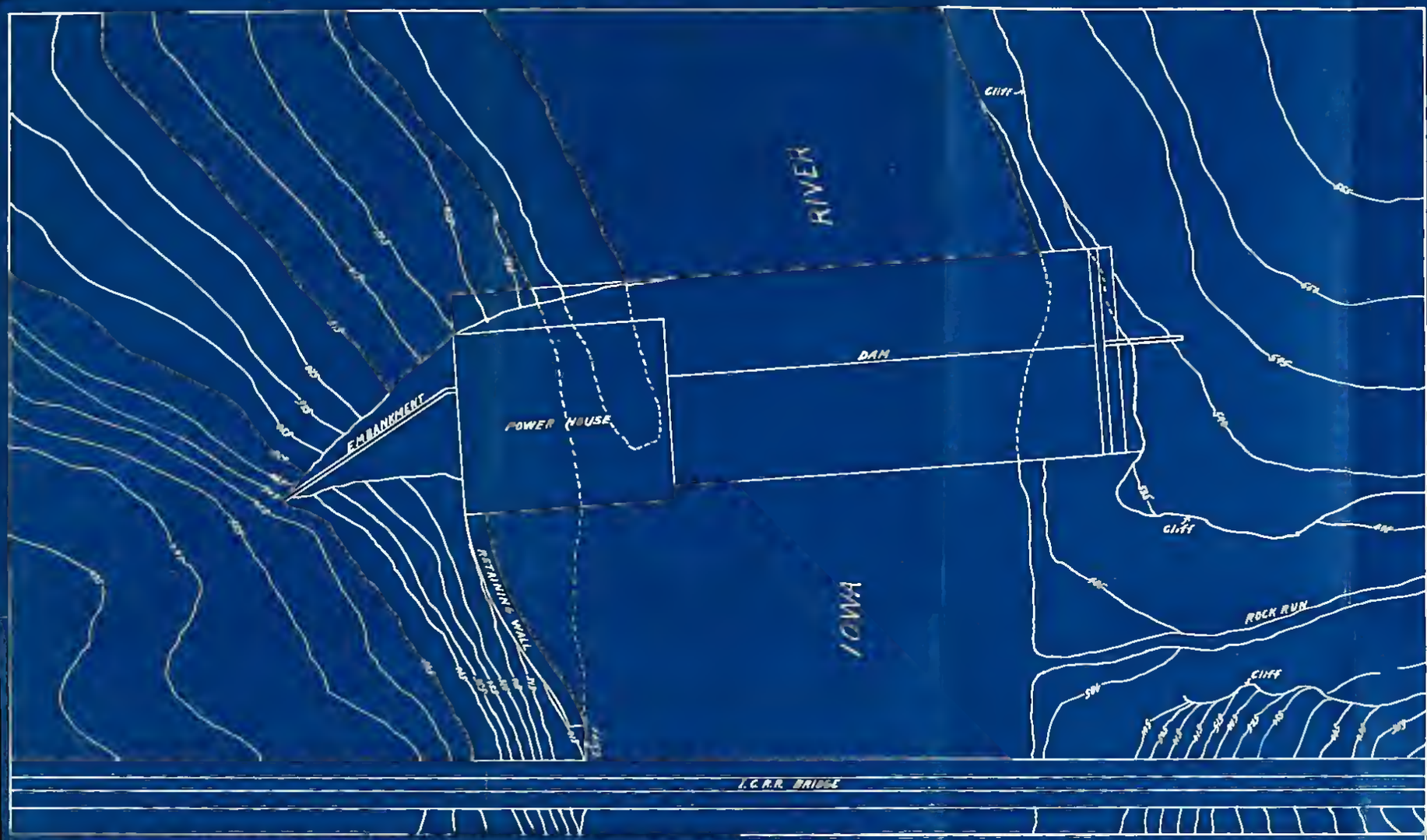
IOWA FALLS,

INSTITUTE of TECHNOLOGY CIVI

O. Dowell

1"=20'

1"=30'



MAP OF LOCATION
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GENERAL ELEVATION OF PLANT
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